Rough Proof.]

Metropolitan Sewers.

SEWAGE MANURE COMMITTEE.

Result of some Inquiries upon the Amount of Water required per Acre by Irrigated Meads, and the Supply obtainable from the Sewers of the Metropolis.

Ordered to be printed, 21*st May*, 1849.

It is pretty certain that the liquid manure of the London Sewers is not sufficiently concentrated to be extensively applicable for the use of the cultivator of arable soil in the immediate neighbourhood of London, or of the market gardener. To this fact, in the case of the Westminster Sewers, the evidence of the London Sewage Manure Company appears to concur with that of several others. We can, then, perhaps, only reasonably look to water meads for the profitable and sufficiently extensive consumption of the sewage of the Metropolitan Districts. For this purpose we may safely regard its value to be undoubted. It is essential, however, for their sufficiently extensive employment,—

1. That the sewage shall be raised from the sewers by powerful engines.
2. That it shall be carried in convenient pipes or channels to a considerable distance from thickly-populated places.
3. That the districts where it shall be thus used in irrigated meadows should be extensive, and possess a suitable soil for the construction of water meads.
4. It is desirable that such meads should be constructed on unequal elevations, so as to allow of the irrigating fluid being readily used a second time, as in the new meads at Edinburgh (see *Mr Buchanan's Report*, post, p. 6).

In calculating the probable value of the sewage of towns to the citizen and to the irrigator, it may be useful to endeavour to form some estimate, however imperfect, of the quantity of liquid required for the irrigation of a given extent of land. This, it is true, can only be accurately determined by the examination of the soil upon which the irrigating water is allowed to flow, as the amount is not only influenced by the composition of the surface soil, but also by the more or less porous nature of the substratum on which it rests. (*See Report of Mr Buchanan*, post, p. 6.) It is indeed evident that the immediate soakage from an irrigated soil which rests on a porous sand, for instance, will be rapid, whilst from the same kind of soil with an understratum of clay the filtration will be much slower. Hence it is certain that the stream of water sufficiently copious for the rapid irrigation of one kind of soil would be too quickly absorbed by the porous substratum of another, to allow of its diffusion over the surface soil with the same, or perhaps sufficient rapidity.

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Still, as the surface soil in most ordinary cases partakes very materially of the composition of the substratum or rock on which it rests, it can hardly fail of producing useful practical results to the owner of lands, suitable for irrigation either by common or sewer water, if we examine the quantity of moisture contained in various soils when *saturated* with water. Upon this question, M. Schubler, in a work translated by Mr James Hudson, gives the results of a series of trials in which he evinced considerable skill and industry (*Jour. R. A. S.*, vol. i, p. 182). This distinguished German chemist thus explains the objects of the investigation, and the necessary precautions required for the experiments to determine what he denominates "the power of the earths to contain water."

"We understand" he observes, "by the power of the earths to hold or contain water, their property of receiving and retaining more or less water within their interstices, without allowing it again to flow away by dropping. It is of the greater importance to vegetation, as on it depends the quantity of the means of aqueous nourishment the soil is in a condition to receive and supply to the roots of plants." The power of an earth to contain water may be found in the following manner :— We take 400 grains of the earth to be examined, and dry it at a temperature of about 144½ degrees Fahrenheit, until it ceases to lose weight. We put the dried earth on a round filter, consisting of unsized paper, and which had been previously weighed in its thoroughly moistened state and laid in a glass funnel or on a linen stretched over a frame. We now pour over the earth lying on a filter water, until it is fully moistened and saturated. We then bring it, while remaining in this wet state, to the balance. It was by this mode that the Professor determined the amount of water in the soils, as given in the following table*:—

	Real quantity of water in a cubic foot, when saturated.	Weight of a cubic foot when dry.	Weight of a cubic foot, when saturated with water.
Calcareous sand . . .	31.8lbs.	113.6lbs.	141.3lbs.
Silicious sand . . .	27.3	111.3	136.1
Sandy clay . . .	38.8	97.8	129.7
Loamy clay . . .	41.4	88.5	124.1
Stiff clay, or brick earth . .	45.4	80.3	119.6
Pure grey clay . . .	48.3	75.2	115.8
Pipe clay . . .	47.4	47.9	102.1
Garden mould . . .	48.4	68.7	102.7
An Arable soil . . .	40.8	84.5	119.1
Fine slaty marl . . .	35.6	112.0	140.3
Gypsum powder . . .	27.4	91.9	127.6
Fine carbonate of lime . .	47.4	53.7	103 5
Fine carbonate of magnesia .	62.6	15.8	76.3

* The reason why the real quantity of moisture in a soil cannot be accurately determined by merely comparing the weight of a given measure when dry, with the same measure when wet, is that some soils when they are dried materially contract, and expand when wet.

If we calculate the mean amount of water in these thirteen varieties of saturated soils to be equal to 42lbs. per cubic foot of earth, or 378lbs. per square yard of soil a foot deep, then 378 × 4,840 (the number of square yards in an acre) gives 1,829,520lbs. of water needed to saturate an acre of *perfectly dry* land to the depth of one foot or about 816 tons.

If we suppose that the saturation of the soil need only extend to a depth of nine inches, then about 543 tons of water would be sufficient; if a depth of only 6 inches, then 408 tons; and if to only a depth of 4 inches, then 273 tons would suffice.

It appears from the recent report of Dr J. Stark (*Statement on Sewer Manure by Mr E. Chadwick*, p. 49), that the celebrated Craigentinny Meads near Edinburgh are annually irrigated by the City Sewage about eighteen times. For instance, a certain plot was watered in its turn, in 1845, May 3 and 14, June 3 and 20, August 15 and 31, Oct. 8 and 29, Nov. 24, Dec. 31; in 1846, Jan. 30, Feb. 18, March 5 and 22, April 2 and 13.

Now, if we calculate that, on an average of months, 250 tons of irrigation water would suffice to saturate the soil (*always partially and sometimes thoroughly previously moistened*), then it would require 4,700 tons of water to give these eighteen irrigations to an acre of land. We deem the quantities we have stated as likely to be an average amount of sewage fluid required for the irrigation of an acre of grass land to be nearly correct. In the recent report of Mr George Buchanan, Engineer for the Irrigated Meads of Craigentinny, near Edinburgh, to the Commissioners of Metropolitan Sewers, he states the quantity of water necessary per acre (p. 6) to be equal to a stream of sewer fluid of $3\frac{1}{4}$ cubic feet per minute for 12 days of 10 hours each. Now this we calculate to be equal to $3\frac{1}{4} \times 60 \times 10 \times 12 = 23400$ cubic feet, weighing $62\frac{1}{2}$lbs. per cubic foot, or $62\frac{1}{2} \times 23400 = 1.462.500$lbs., or about 650 tons. It will be remarked, however, that the sewage fluid in this case had to sustain the soakage, leakage, and evaporation during thirteen days of the month of May. This slow irrigation is far from being the most economical mode of applying the sewage—the more rapid and copious application being to be preferred, as affording little time for the soakage of the substratum, and the leakage from the soil into the drains, and evaporation from the surface. Mr Buchanan also adds (see *post* p. 7), "In some parts the soil consists of very stiff clay, resting on a similar substratum, and other parts of a red sand, and the sand requires nearly twice as much water for saturation as the clay."

We see, then, that the amount stated by Mr Buchanan of about 700 tons per acre having been used at Edinburgh upon a mead, and subject to many deductions from its saturating power, is not very widely different from the average amount of about 800 tons required, according to Professor Schubler, to saturate the same extent of nearly chemically dry earths. Then, again, by avoiding the soakage and drainage waste of twelve days, and taking the average of moderately retentive soils, a very material saving would undoubtedly be accomplished; and, moreover, by raising the sewage fluid to the contemplated elevations, it would be available for the use of the irrigator a second time (see *Mr Buchanan's Report*, p. 6). Upon the whole,

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therefore, we deem the calculated quantity of 4,700 tons per acre annually to be a tolerable approximation to the truth. Some persons may deem 4,700 tons of sewer fluid to be an enormous yearly application of water: to such persons it may be useful to be reminded that the mean depth and weight of rain which annually falls at King's Langley, in Hertfordshire (*Mr J. Dickinson, Jour., R.A.S.*, vol. v, p. 151), is equal to 26.61 inches, or 2695 tons per acre. Of this, from April to September inclusive, the mean depth which fell was equal to 12·67 inches, or 1 283 tons per acre,* of which 1192 tons were lost by evaporation, and only 92 tons filtered away through the soil. From October to March, inclusive, the mean depth of rain was 13.95 inches, or 1412 tons, of which 1052 filtered down through the soil, and only 360 tons evaporated.

In making the experiments, the surface of the soil exposed to the evaporating influence of the sun and wind is supposed to be bare of herbage. In the case of a water mead densely covered with a luxuriant and rank crop of grass, the evaporating surface is very materially increased, and the demand upon the soil for moisture is pretty certainly proportionately enlarged.†

Taking then these data, allowing upon an average 250 tons per acre of sewage water to each irrigation (or a depth of 2½ inches), and taking the daily extent of the sewage of the Metropolis to be equal to an area of 50 acres, 36 inches deep, we have here offered to us sufficient water for the *daily irrigation* of 750 acres of grass-land. But, as we have seen in the case of the Edinburgh meads, that they are irrigated only 18 times in the year, then we find that the sewage of the Metropolis is equal to the irrigation of 15,000 acres of water meads. It is not difficult to estimate the money value per acre to the farmer of the thus applied sewage water. Dr Stark says (*Statement*, p. 49), "the more water each portion receives, the larger is the crop raised upon it, and the higher the price got for that crop in the market; so that while the lots which are watered only once in the fortnight in general bring only from 23*l.* to 30*l.* per acre annually, those which receive a larger supply let for from 28*l.* to 50*l.* per acre." Now if we take the mean rent of thus

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* In some of the northern English districts it is double this amount, or at least 5,500 tons per acre. In no instance has Mr Dickinson noticed so great a fall of rain as 1½ inches (or 150 tons per acre) in 24 hours (*ibid, p.* 153), and yet how often and how thoroughly does a November day's rain often supersaturate the soil!

† The larger evaporation from a soil tenanted by plants was shown experimentally by Mr George Phillips (*Jour. R.A.S. vol.* vii, *p.* 307). He employed in the month of March two metallic vessels of equal size, which were used as mould pots. They were so constructed that no moisture could escape except at the surface. Each pot contained 22.09 square inches of surface at the level of the mould. One pot was filled with mould only, the other with mould containing a polyanthus, and in another experiment three plants of the potato. In twelve days the mould evaporated 1600 grains, or 6.06 grains daily per square inch, while the pot containing the polyanthus had evaporated 5250 grains, which for the mould and one surface of the leaves is 4.93 grains for every square inch. In the case of the potato plants, in nineteen days the mould evaporated 54,000 grains; the potato plants, 3,000 grains. The daily evaporation from one surface of the potato was at the rate of 1.4 grain, and of the polyanthus 2.1 grains from one square inch.

In the experiments of Dr Hales on a sunflower, the daily mean evaporation was 15 grains for every square inch of the plant's surface.

similarly irrigated meads near London to be 25*l.* per acre (the best meadows of Edinburgh yield from four to five cuttings annually, the poorest three cuttings only), and that the owners would gladly give 12*l.* per acre annually for the use of the sewer irrigation water, to the extent to which we have alluded, we should thence receive an income of 12*l.* × 15,000*l.* = 180,000*l.* per annum for the agricultural use of the Metropolitan sewage water alone; an income equal, after the payment of four per cent. interest on a capital of 2,000,000*l.*, to the payment of 100,000*l.* per annum in coals for steam-engines, repairs, wages, &c. Thus there is every probability that this proposed mode of dispersing the sewage of London will be a source of gain rather than of loss to the rate-payers; whilst to the community at large, besides other great and direct advantages, the thus doubling or trebling the produce of the irrigated soil is the same thing as adding an equal number of acres to the productive lands of the country.

(Signed) CUTHBERT W. JOHNSON.

May 21, 1849.

APPENDIX.

ANSWERS TO QUERIES of the Metropolitan Commissioners of Sewers as to the Sewage Irrigation of the Edinburgh Meadows, by GEORGE BUCHANAN, Civil Engineer, Edinburgh, F.R.S.E., Engineer for the Irrigated Meadows of Craigentinny.

14 Duke street, Edinburgh,
1st *May*, 1849.

DR JAMES STARK,

DEAR SIR,

Agreeable to your request, I now send you the following answers to the queries as far as my information and experience go.

1st.—"Can you give any approximate estimate of the quantity of sewage fluid required to once thoroughly saturate the soil of a given measure of the meadows?"

3rd.—"In reference to the 177 acres of land which you state to be already irrigated by a portion of the Edinburgh sewage, and the fifty acres to which that portion is about to be extended, can you furnish us with an estimate of the amount of ordinary flow of sewage water through the main sewer or sewers by which those meadows are now or will be irrigated?"

By a Report of mine, dated 23rd August, 1845, I calculated from numerous

observations that the average supply of water running in the sewage burn at Craigentinny was 220 cubic feet per minute, or that the extent of meadows irrigated by this quantity was about 180 imperial acres, making about $1\frac{1}{3}$ cubic feet per minute to each acre. But on observing the operations at different times, I was satisfied that this water might have irrigated a much larger extent, because a great proportion of the water, I should say nearly one half, after irrigating and saturating the meadows, was found running to waste in the watercourses towards the sea ; and it was partly this consideration which led me to advise the system of pumping, by which the water, being let on at a higher level, could be made available in irrigating a large extent of new meadow on this level, and afterwards the waste water employed in irrigating the lower meadows then existing. In some parts of the season also there was not one fourth or one half of this supply in the burn, and still the meadows were fairly watered. There can be no doubt, therefore, that $1\frac{1}{3}$ cubic feet per minute affords a prodigal supply for irrigating each acre, such as the meadows here referred to; and less than one half would be in many cases sufficient: but in such extensive meadows it is not practicable, nor would it be proper, to distribute the water continually over the whole land. It is found best to concentrate it on different districts so as to employ the whole water running over each for about a fortnight or three weeks, and embracing about ten or fifteen acres each day. This of course would give in proportion a larger flow per minute for each acre during the period of actual watering.

It was the consideration of the loss of the waste water which led to the extension of the meadows, and to the erection of the pumping machinery for lifting the water, which was all done by my advice and direction ; and besides the water from the burn, a small additional supply was obtained from an Artesian well bored to a considerable depth into the rock at the farm-house, and also from springs and drainage found in the mine, which was run for a considerable extent from the irrigating feeder twenty feet under the surface of the ground, to the farm-house, where the engine and pump is situated. The result of the pumping operations, so far as it has gone, has been very satisfactory, and shows that the land may be irrigated with a much less supply of water than what is used in the lower meadows, although, at the same time, no doubt a larger supply would be still more beneficial.

The additional extent of meadow to be brought in by a 15-feet lift of water was calculated at 90 acres, which would have required, at the rate of $1\frac{1}{3}$ cubic feet, 120 cubic feet per minute; but allowing 20 or 30 for waste, I considered that 80 or 90 feet per minute would be an ample supply, and designed the pumping machinery with the view of lifting this quantity, and having a 6-horse engine already on the farm for working the thrashing mill, I considered this would be sufficient for lifting the water, by making the pumps of suitable capacity, and this was 16 inches diameter, and nearly 4-feet stroke, making 15 strokes per minute. The process of watering for the season is now going on, and during the last fortnight 37 imperial acres have been watered by the pumps going 10 hours per day for 12 days, and drawing at the rate of 120 cubic feet per minute. This is at the rate of $3\frac{1}{4}$ cubic feet per acre during the period; but of course more or less can be thrown on at pleasure by concentrating the water over a smaller extent, and continuing the pumping for a longer period to embrace the whole.

2nd Query.—"The different proportion of sewage water needed according to the nature of the soil and subsoil?"

In some parts the soil consists of very stiff clay, resting on a similar substratum, and other parts of a bed of sand, and the sand requires nearly twice as much water for saturation as the clay.

GEO. BUCHANAN.

Edinburgh, May 7, 1849.

NOTE OF THE EXTENT OF NEW MEADOWS AT CRAIGENTINNY.

Of the 90 acres of new meadows proposed to be taken in, only 73 have been executed, leaving the remainder still to be done, and all as proposed by the same pumping machinery. Besides this, 4 imperial acres have been added to the lower meadows.

GEO. BUCHANAN.

Edinburgh, May 8, 1849.

EXTRACT FROM A LETTER FROM MR ROE TO MR CHADWICK, DATED JUNE 6, 1849.

My land (meadow) is drained to a depth of 2 feet, and the outlet for the drains is into a tank from whence I again pump the water for use a second time (the tank has an overflow drain). Soon after the irrigation commences I find the water in my drains run freely, and the water still exceedingly good. The tank need not be very large if the water is pumped out as it flows in.

This land has an understratum of clay, having a depth of 18 inches of alluvial soil on the top.

I cut my crop in April and the beginning of May, and began cutting my second crop the last week in May.

Last year I cut five crops, and left a good feed after. A quarter of an acre kept my horse thirty weeks, with only two trusses of hay in addition. I have not the least doubt but that I shall cut seven crops this year, worth to cowkeepers at least from 6*l.* to 7*l.* per acre each crop.

The quantity of water I used to each irrigation last year was 50 cwt. to each four poles of ground, or 100 tons to one acre. This spring I have used at the rate of 200 tons, and the result has been on that portion that in one month after the first cutting the grass is what is termed lodged.

I have only irrigated twice in the winter and once immediately after each cutting.

The water I use passes partly through the dung pit; the contents of a water closet used by three people, and the urine from one horse, pass to the tank, so that sewer water (unmixed with rain water), is much stronger than the water I use.

I am, &c.,

(Signed) JOHN ROE.

E. Chadwick, Esq., &c. &c. &c.

Metropolitan Commission of Sew

SEWAGE MANURE COMMITTEE.

Result of Inquiries as to Quantities of Wa required per Acre for Irrigated Lands, and Supply of Sewage obtainable from the M tropolis.

May, 1849.

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